

FUEL INJECTOR

## Background Information

The present invention relates to a fuel injector in accordance with the species of the main claim.

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A fuel injector is already known which has a valve needle, that is controlled by an actuator. The actuator is composed, e.g., of an electromagnetic coil or a piezo element. An exemplary fuel injector of the species, having an  
10 electromagnetic coil, is described in German Patent 35 40 660 C2. The fuel injector has a valve housing, in which a solenoid coil is arranged on a coil support. A valve needle, having a valve closure member that is configured on the former as one piece, cooperates with a valve seat surface forming a sealing  
15 seat. At its end facing the solenoid coil, the valve needle is fixedly connected to an armature and is acted upon by a resetting spring against the sealing seat. If a current flows through the solenoid coil, the armature is pulled against the force of the resetting spring and lifts the valve needle off  
20 from its sealing seat. The fuel can then exit through a spray-discharge bore hole which adjoins the valve seat.

A disadvantage in this known fuel injector is the fact that the angle at which the injection takes place is fixed, and the  
25 quantity of fuel can only be regulated to a very limited degree. It is difficult or impossible to make adjustments with respect to various operating states, such as are necessary in particular in the case of lean-mixture concepts and stratified-charge methods in combination with direct injection  
30 into the combustion chamber. For this purpose, it is necessary to attain varying operating states using injection angles that vary in their direction.

From German Patent 30 48 304 A1, a fuel injector is known for internal combustion engines, having a valve needle and an auxiliary needle in a bore hole of the valve needle. The valve needle, at its segment on the combustion-chamber side configured as a valve closure member, cooperates with a valve seat surface to form a sealing seat, which separates spray-discharge bore holes from a fuel supply. The auxiliary needle, guided in the valve needle, also has a valve closure member, which cooperates with a second valve seat surface of the fuel injector. As a result of a spring placed in the valve needle, the auxiliary needle is pulled against the valve needle, in which direction it also forms a sealing seat along with a valve seat surface in the valve needle. If the hydraulically actuated fuel injector begins to open as a result of an increase in the pressure in the fuel supply line, then the auxiliary needle is pressed from its sealing seat in the valve needle against the sealing seat in the valve body and closes a group of spray-discharge bore holes, while a further group of

From German Patent 27 11 391 A1, a fuel injector having an operating piston is known for regulating the maximum stroke of a valve needle. The valve needle is acted upon in the closing direction by a spring and cooperates with a valve seat surface to form a sealing seat. The valve needle is controlled purely hydraulically. Using the operating piston, which is also hydraulically adjustable in its stroke, the stroke of the valve needle is limited, or completely prevented. Driving this operating piston is accomplished using its own supply line. In accordance with the stroke of the operating piston, the through-flow quantity of fuel can be limited. It is disadvantageous in the fuel injector that the design is multi-part and cumbersome, and therefore is expensive to manufacture.

In contrast, the fuel injector according to the present invention having the characterizing features of Claim 1 has the advantage of making possible in the combustion chamber of an internal combustion engine a distribution of the fuel that is adjusted to the requirements of the performance characteristics and, in particular, of a lean-mixture concept.

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the jet image of the fuel injector can be modified as a function of the valve stroke. This is assured in the fuel injector according to the present invention by the second valve closure member and by having the valve needles driven by a common actuator. The fuel injector can be opened in two stages, the sealing seats being opened one after the other.

Through the measures indicated in the subclaims, advantageous refinements and improvements of the fuel injector indicated in Claim 1 are possible.

Advantageously, as a result of the two sealing seats of the two valve needles, two different hole circles, made up of spray-discharge bore holes, can be actuated.

In particular, the spray-discharge bore holes of the different hole circles can have different spray-discharge angles and can be offset with respect to each other. Advantageously, when the injection quantities and the loads of the internal combustion engine are slight, it is initially possible to open only a first hole circle. The latter has, e.g., a narrow spray-discharge angle of the spray-discharge bore holes, so that a fuel injection jet is formed having overall a narrow angle range. In response to higher loads of the internal combustion engine and to the corresponding requirements in the stratified-charge operation of an internal combustion engine that is operated using a lean-mixture concept, the spray-discharge bore holes of the second hole circle are opened. The bore holes can be arranged at a greater spray-discharge angle.

#### Drawing

One exemplary embodiment of a fuel injector in accordance with the species as well as exemplary embodiments of the present invention are depicted in the drawings in simplified form and are discussed in greater detail in the description below. The following are the contents:

Figure 1 depicts a section of a fuel injector of the species, having a valve needle that is controlled using an actuator,

5 Figure 2 depicts a segment of a first exemplary embodiment of a fuel injector according to the present invention in a cutaway view,

10 Figure 3 depicts a segment of a second exemplary embodiment of a fuel injector according to the present invention in a cutaway view, and

15 Figure 4 depicts a segment of a third exemplary embodiment of a fuel injector according to the present invention in a cutaway view.

#### Description of the Exemplary Embodiments

20 Before three exemplary embodiments of a fuel injector according to the present invention are described in greater detail on the basis of Figures 2 through 4, an already known generic fuel injector will first be briefly discussed on the basis of Figure 1 with respect to its essential components in order to achieve better understanding of the present  
25 invention.

Fuel injector 1 is executed in the form of fuel injector for fuel injection systems of mixture-compressing, spark-ignition internal combustion engines. Fuel injector 1 is especially  
30 suited for the direct injection of fuel into an undepicted combustion chamber of an internal combustion engine.

Fuel injector 1 is composed of a nozzle body 2, in which a valve needle 3 is guided. Valve needle 3 is in an operative  
35 connection with a valve closure member 4, which cooperates with a valve seat surface 6, arranged on a valve seat body 5, forming a sealing seat. In the exemplary embodiment, fuel

injector 1 is a fuel injector 1 that opens to the inside,  
 which is provided with a spray-discharge opening 7. Nozzle  
 body 2 is sealed by a gasket seal 8 against outer pole 9 of a  
 solenoid coil 10, which functions as an actuator. Solenoid  
 5 coil 10 is encapsulated in a coil housing 11 and is wound on a  
 coil support 12, which contacts one interior pole 13 of  
 solenoid coil 10. Interior pole 13 and exterior pole 9 are  
 separated from each other by a gap 26 and are supported on a  
 connecting part 29. Solenoid coil 10 is excited via a line 19  
 10 by an electrical current that is supplied over the electrical  
 plug-in contact 17. Plug-in contact 17 is surrounded by a  
 plastic sleeve 18, which can be injection-molded on interior  
 pole 13.

Valve needle 3 is guided in a valve needle guide 14, which is  
 executed in a disk shape. To adjust the stroke, there is a  
 separated adjusting disk 15. Located on the other side of  
 adjusting disk 15 is an armature 20. The latter is connected  
 via a flange 21 to valve needle 3 in a force-locking manner,  
 20 the valve needle being joined to flange 21 by a welded seam  
 22. Supported on flange 21 is a resetting spring 23, which in  
 the present design of fuel injector 1 is biased by a sleeve  
 24. Running in valve needle guide 14, in armature 20, and on  
 valve seat support 5, are fuel channels 30a through 30c, which  
 25 convey the fuel to spray-discharge opening 7, the fuel being  
 supplied via a central fuel supply line 16 and being filtered  
 through filter element 25. Fuel injector 1 is sealed by a  
 gasket seal 28 against a cylinder head, or a fuel distributor,  
 which is not further depicted.

In the resting state of fuel injector 1, armature 20 is acted  
 upon by resetting spring 23 opposite to the stroke direction,  
 so that valve closure member 4 is held in the sealing position  
 on valve seat 6. In response to the excitation of solenoid  
 35 coil 10, the latter generates a magnetic field, which moves  
 armature 20 in opposition to the spring force of resetting  
 spring 23 in the stroke direction, the stroke being stipulated

If the coil current is switched off, after a sufficient degradation of the magnetic field, armature 20 falls away from interior pole 13, due to the pressure of resetting spring 23, as a result of which flange 21, in an operative connection to valve needle 3, moves in opposition to the stroke direction. Valve needle 3 in this way is moved in the same direction, as a result of which valve closure member 4 is placed on valve seat surface 6, and fuel injector 1 is closed.

The section depicted in the cutaway view in Figure 2 of a first exemplary embodiment according to the present invention shows a valve body 31, which is configured in one piece along with valve seat body 32 and which has, e.g., a truncated-cone valve seat surface 33. A valve needle 34 is formed in one piece along with a first valve closure member 35, which cooperates with valve seat surface 33 to form a first exterior sealing seat 36. Guided in a bore hole 37 of valve needle 34 is a second valve closure member 38, which is acted upon by a force exerted by a spring 39, which is supported against a bore hole base 37a of valve needle 34. Second valve closure member 38 cooperates with a second valve seat surface 40, which is arranged in valve seat body 32, forming a second interior sealing seat 41. In the embodiment described here, first valve seat surface 33 and second valve seat surface 40 are favorably provided as one single continuous surface in valve seat body 32, as a result of which they are advantageously shaped from the production-technical point of view.

If valve needle 34 is lifted by the actuator from its first sealing seat 36, then initially only first hole circle 45 having its spray-discharge bore holes 44 is released. Only when collar 42 of second valve closure member 38 contacts limit stop 43 of valve needle 34 after a partial stroke  $h_1$  is second valve closure member 38 also lifted from its sealing seat 41, and spray-discharge bore holes 44, 47 of second hole circle 46, or centrally oriented spray-discharge bore hole 47, is released. As a result, it is possible to individually adjust the angle at which the fuel injection jet fans out, taking into account the requirements of a stratified-charge concept, or of a lean-mixture concept. It is only possible to open valve needle 34 in a stroke that is smaller than partial stroke  $h_1$ . If spray-discharge bore holes 44 of first hole circle 45 have a smaller angle with respect to longitudinal axis 48, then the fuel injection jet, which arises and is here not further depicted, only fans out at a small angle in the combustion chamber. On the other hand, if a broad fanning out of the fuel injection jet at a large angle is desired, then, as a result of an overall stroke of valve needle 34 that is



greater than partial stroke  $h_1$ , second valve closure member 38 can also be lifted off from its sealing seat 41, and both hole circles 45, 46 are opened. Through additionally opened spray-discharge bore holes 44, which can have a different angle, it is possible to achieve a different shape of the fuel injection jet.

Figure 3 depicts a segment of a second fuel injector according to the present invention in a cutaway representation of the lower segment, which is facing the undepicted combustion chamber. A valve body 49 is configured in one piece along with a valve seat body 50. A valve needle 51, which is configured in one piece along with a first valve closure member 52, cooperates with a valve seat surface 53 to form a first interior sealing seat 54. A second valve closure member 55 cooperates with a second valve seat surface 56 to form a second exterior sealing seat 57. Second valve closure member 55 is supported via a spring 58 against an intermediate plate 59 of valve body 49.

Serving as a limit stop of valve needle 51 is a circumferential collar 60 of valve needle 51. The counter limit stop of second valve closure member 55 is a circular groove 61 in an interior bore hole 62 of second valve closure member 55, through which valve needle 51 passes. Fuel supply 63, which is indicated here by an arrow, is accomplished circumferentially outside of valve needle 51 and of first valve closure member 52, and radially within second valve closure member 55, e.g., in a gap or one or more grooves between these two valve closure members 52, 55. A further fuel supply leading to exterior spray-discharge bore holes 64, which are arranged in valve seat body 50, is constituted radially outside second valve closure member 55 of surrounding chamber 71.

Opposite fuel supply 63, a first interior hole circle 65, composed of spray-discharge bore holes 64, is sealed by first

sealing seat 54. A second exterior hole circle 66, made up of spray-discharge bore holes 64, is sealed by second exterior sealing seat 57, opposite fuel supply 63. Second valve closure member 55 on a third valve seat surface 68, which is arranged in valve seat body 50, has a third sealing seat 69, which seals second hole circle 66 opposite surrounding chamber 71, which is filled with fuel. A further spray-discharge bore hole 64 is provided as a central spray-discharge bore hole 67 in valve seat body 50.

If valve needle 51 is lifted by the undepicted actuator, and if the stroke is smaller than partial stroke  $h_1$ , then valve needle 51 is lifted, and first sealing seat 54 is released. Only spray-discharge bore holes 64 of first hole circle 65 and a centrally oriented spray-discharge bore hole 67 are now connected to fuel supply 63. If the actuator is activated to the extent that the stroke of valve needle 51 is greater than partial stroke  $h_1$ , then second valve closure member 55 is carried along by collar 60, which strikes against groove 61 in bore hole 62. Second sealing seat 57 is now released opposite fuel supply 63, and third sealing seat 69 opposite surrounding chamber 71. The jet image of the fuel injection jet can now be expanded if second hole circle 66 has a larger spray-discharge angle with respect to a longitudinal axis 70.

Figure 4 depicts a fuel injector, in highly schematic form, in a cutaway cross-section corresponding to a third exemplary embodiment according to the present invention. In a valve body 72, a valve needle 73 is arranged, which is joined to an armature 74 by a welded seam 76. From valve needle 73, a second valve closure member 75 protrudes, similar to the design according to Figure 2. Valve needle 73 is acted upon by a biasing force via armature 74 by a spring 77. At spring 77, core 78 of an electromagnetic actuator closes, whose coil is not depicted here. Arranged around valve needle 73, and fixedly connected thereto, is a stop ring 79. Movably arranged in valve body 72 and supporting itself against a step 82 in

valve body 72 is a limit stop ring 80, which is pressed by a  
second spring 81 against this step 82. If armature 74 and  
valve needle 73 are pulled by the armature, then, after a  
predetermined stroke, stop ring 79 strikes against limit stop  
5 ring 80. To continue to pull valve needle 73, the force of  
spring 81 must also be overcome.

As a result of this design, two different stroke ranges can be  
very well distinguished so as to be easily controllable. In  
10 particular, it is possible to distinguish two opening states  
of the fuel injector in an easily controllable manner, if the  
stroke, after which stop ring 79 comes into contact with limit  
stop ring 80, is selected so that it corresponds to partial  
stroke  $h_1$  of Figure 2.